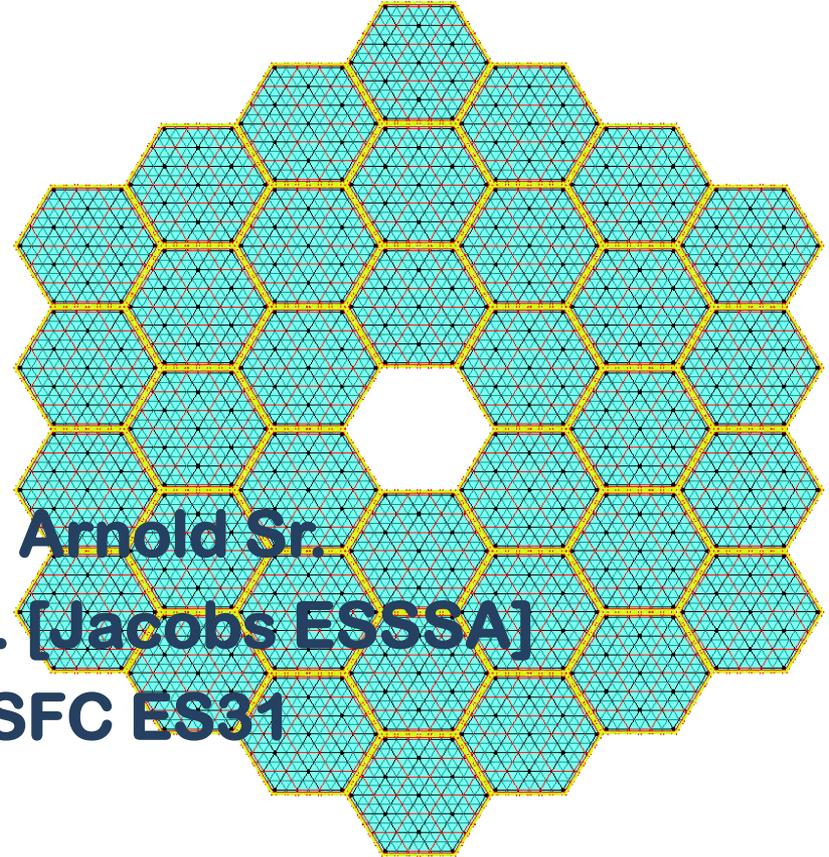
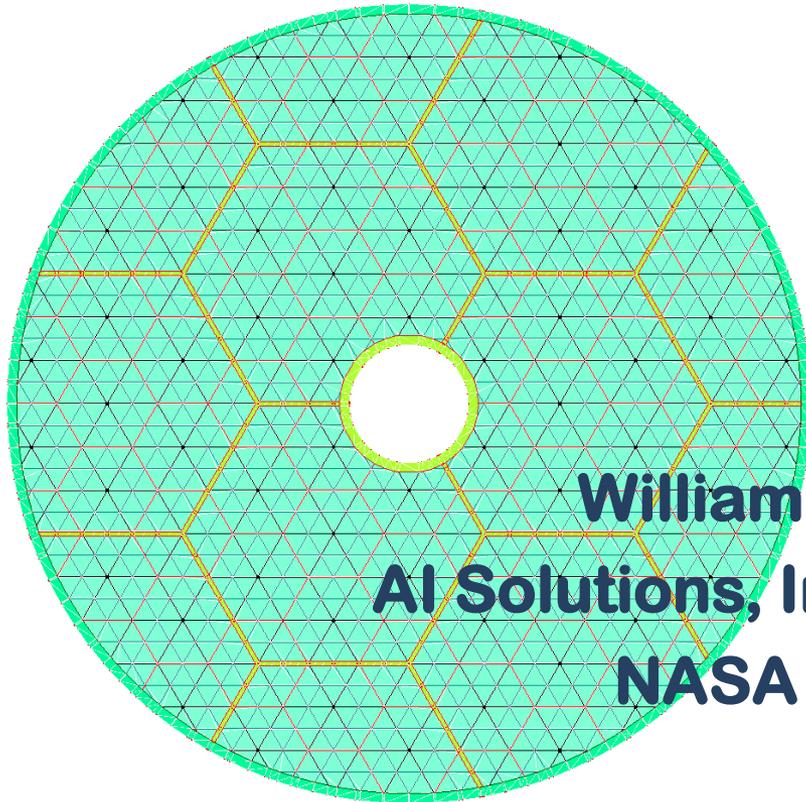


# AMTD Design Process



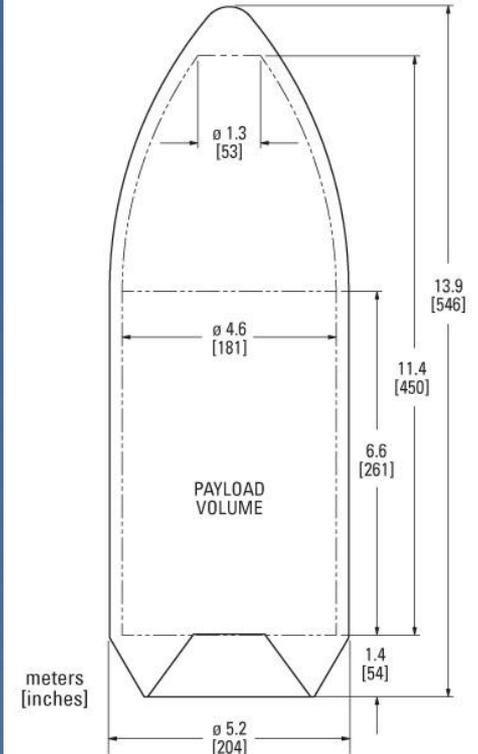
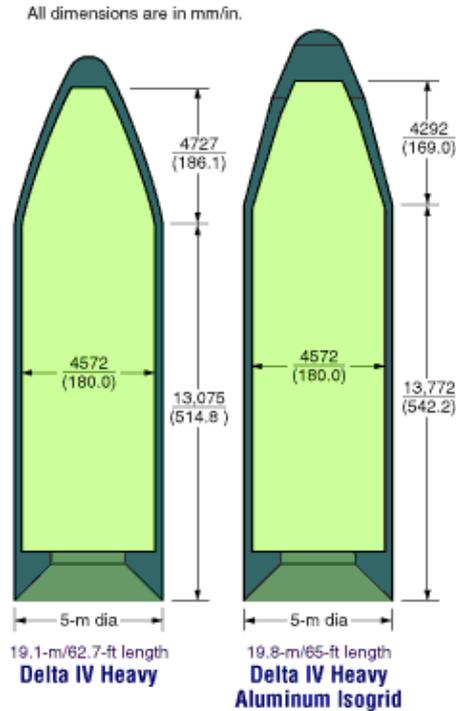
**William R. Arnold Sr.**  
**AI Solutions, Inc. [Jacobs ESSSA]**  
**NASA MSFC ES31**

# Define the AMTD Design Process



- **Objectives of AMTD (why are we doing this?)**
- **Influences of available launch vehicles**
- **What constitutes an “point design”?**
- **How manufacturing capabilities influence the design process.**
- **Mirror, suspension system and deployment mechanisms (if segmented) must be treated as a unit for a design point.**

# Current Launch Vehicles



# What is an Acceptable Design Point?



- **Operational performance [It has to work]**
- **Launch Survival [It has to get into orbit]**
- **Manufacturing Considerations [it has to be made]**
- **Cost and Risk Estimates [It has to be affordable and reasonable risk of success]**

# Operational Performance

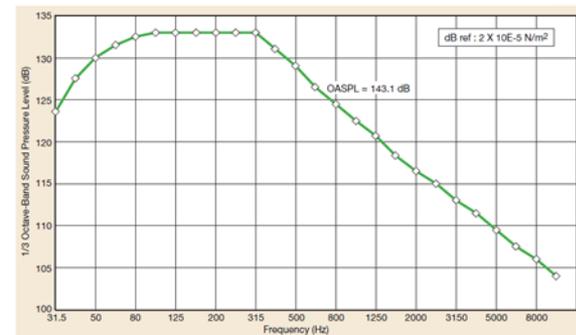
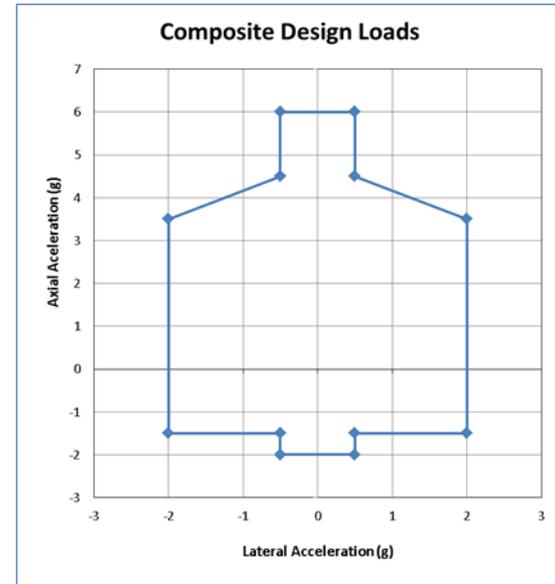


- **Optical Stability**
- **Thermal Stability**
- **Jitter rejection**
- **Optical performance, diffraction, quality etc.**
  - **Monolith versus segmented primary**
  - **Off axis versus On axis**

# Launch Environment

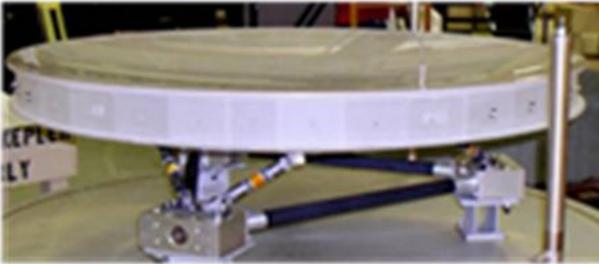
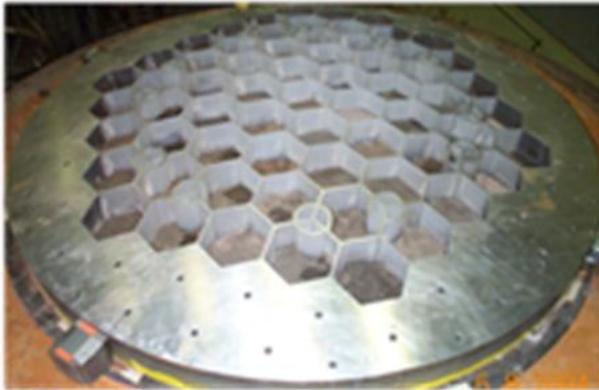


- **Steady State Acceleration**
- **Vibro-Acoustic**
- **Sinusoidal**
- **Random Vibration**
  
- **Support System(s)**
  
- **Shroud Geometry**
- **Payload to L2 Orbit**



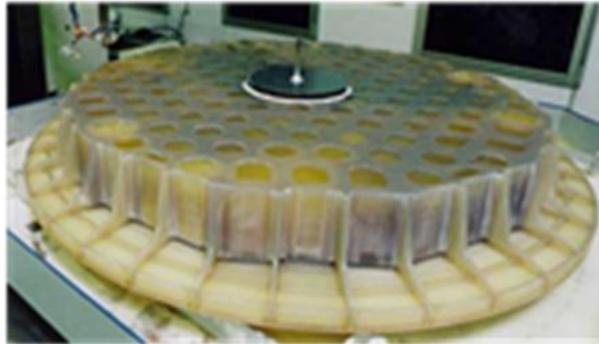
# Manufacturing Considerations

## FRIT BONDED ULE



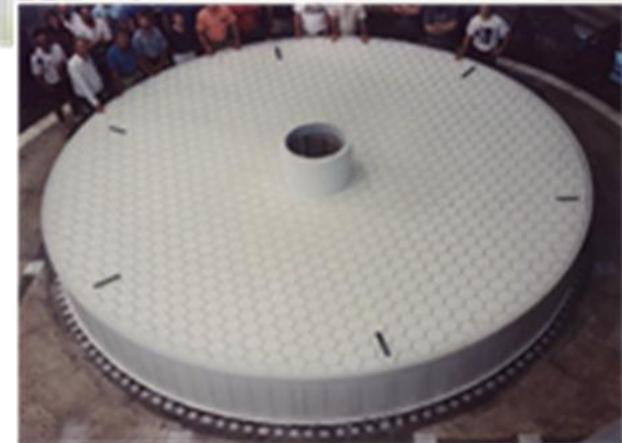
**\*LOW TEMPERATURE FUSION IS AN ALTERNATIVE ASSEMBLY, REQUIRES SLUMPING**

## POCKET MILLED ZERODUR



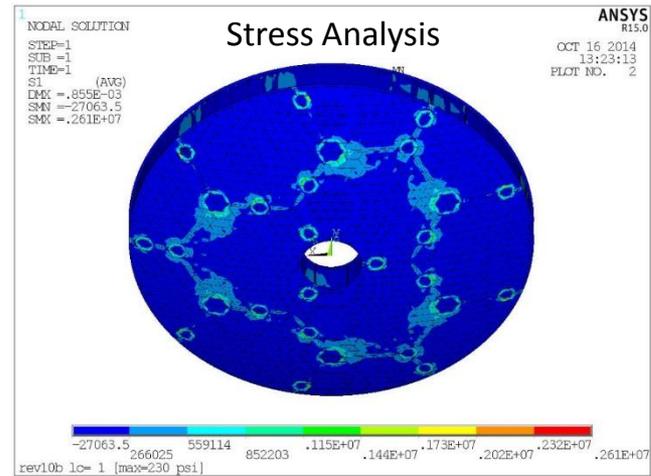
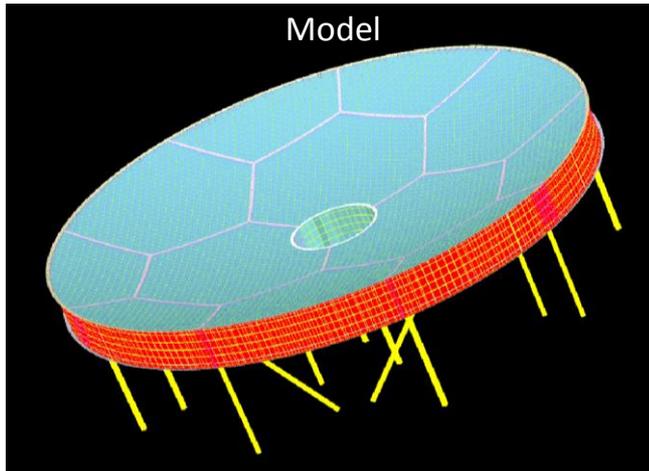
- Can the blank be made?
- Can the blank be transported where needed?
- Can the mirror be processed (flipped etc.)?
- Can the mirror be tested (gravity offset)?
- Can the mirror be coated?
- Can the mirror be transported where needed?

## CAST BOROSILICATE



- **Operational requirements**
  - Kinematic
  - Jitter rejection
  - Thermal and figure control
- **Launch requirements**
  - survive
- **Auxiliary Launch system**
  - Beyond certain diameter versus mirror mass
  - Key characteristics
    - Detach after launch
    - Share load evenly with operational system

# Typical Deep-Core LTF ULE



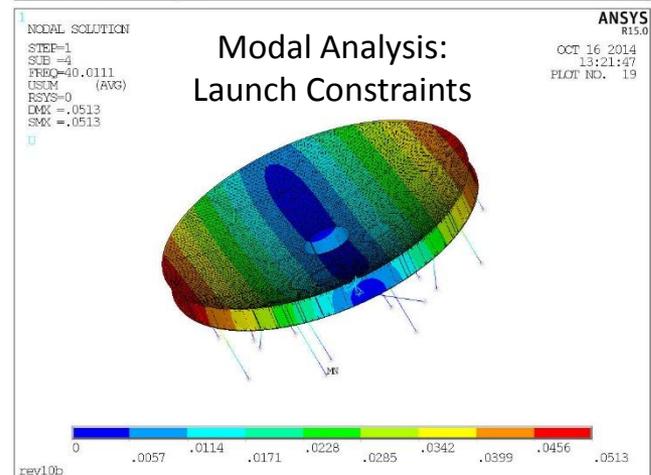
Arnold Mirror Modeler (c2014 version 2.6.13)

Num Rings: 2  
Sgnt Gap: 0.025  
Cell Width: 0.19  
Sgnt Span: 1.52  
Sgnt Lip: 0.0125  
Inner Dia: 0.6  
Inner Lip: 0.0254

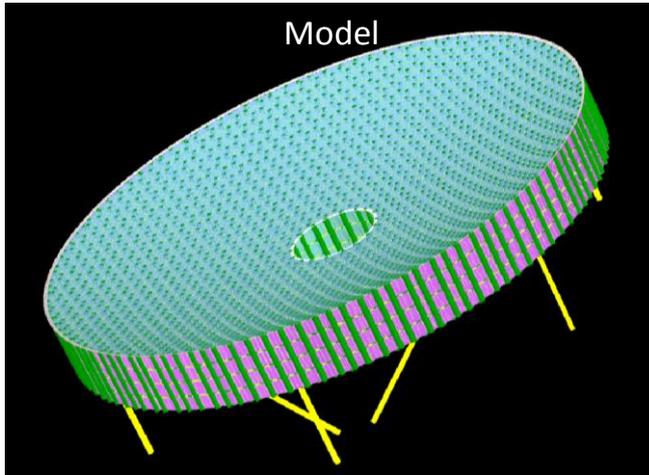
MULTI-SEGMENT  
Outer Dia: 4  
Mirror Lip: 0.0254  
Petals: 2  
Petals ID: 0.5  
Num Petals: 6

Model Statistics  
54128 num Nodes  
123147 num Elms  
1069.211 Weight (kg)  
12.43228 Area (m<sup>2</sup>)  
86.00282 AD (kg/m<sup>2</sup>)  
772.6182 Faces (kg)  
296.8559 Core (kg)  
162.8744 Edges (m)  
0.80553 Milled (m<sup>3</sup>)

Modeler Statistics



# Typical Open-Back Zerodur “Milled”



Arnold Mirror Modeler (c)2014 version 2.6.13

**Modeler Statistics**

63919	num Nodes
108553	num Eloms
1766.539	Weight (kg)
12.38184	Area (m <sup>2</sup> )
142.6718	AD (kg/m <sup>2</sup> )
161.5818	Faces (kg)
1604.896	Core (kg)
213.0596	Edges (m)
8.00954	Milled (in <sup>3</sup> )

Archive Loaded:  ArchivedFile\_e  
Status:   
Finished Writing out Model:   
Operation Duration:   
Lapsed Time: 00:00:06.595

**SINGLE SEGMENT**

Num Rings: 0  
Sgmt Gap: 0.025  
Cell Width: 0.12  
Sgmt Dia: 4  
Sgmt Lip: 0.0254  
Inner Dia: 0.6  
Inner Lip: 0.0254

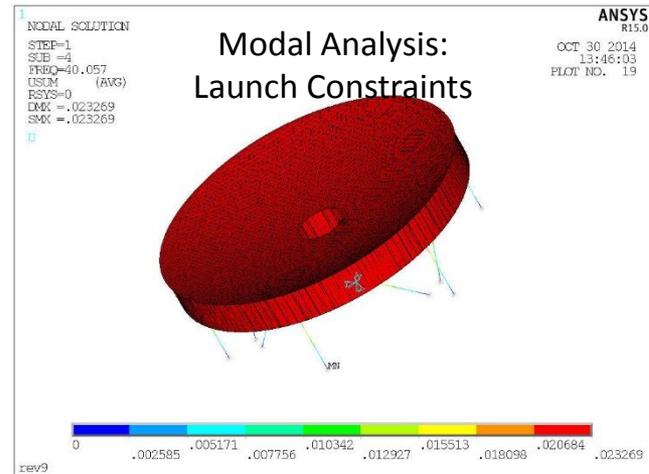
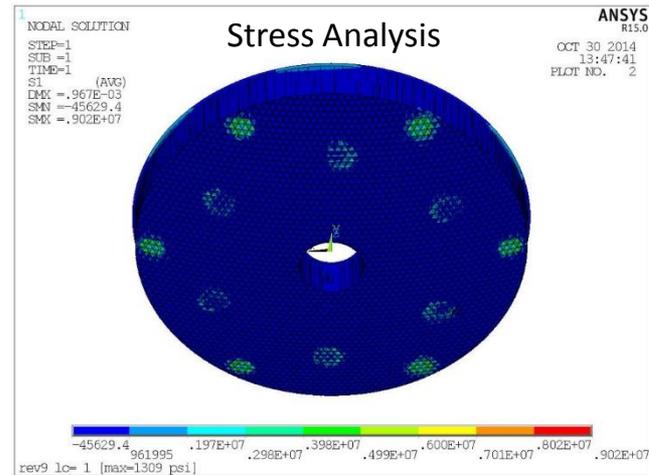
Output Format:  ANSYS,  ABAQUS,  NASTRAN

Options:  Outer Sgmt Lip,  Outer Mirror Lip,  Inner Mirror Lip,  Circular Segment,  Circular Mirror,  Seal Ring Outer,  Seal Ring Inner,  Seal Ring Mirror,  Continuous Seal Rings,  Segment Lip Fills,  Web Centric Grid,  Sgmt. Coord Systems,  Radial Petals

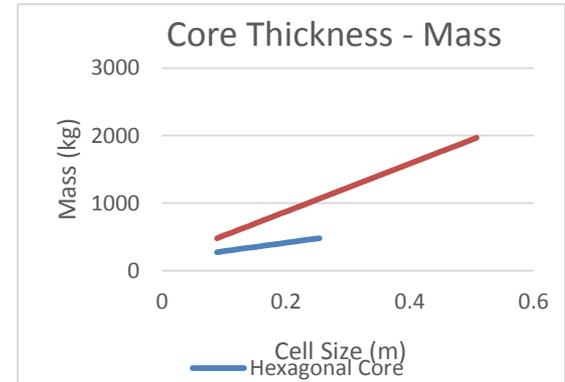
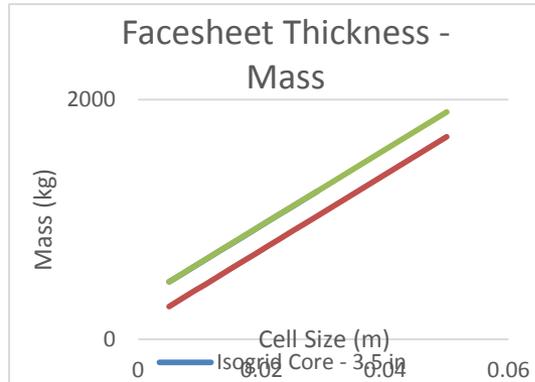
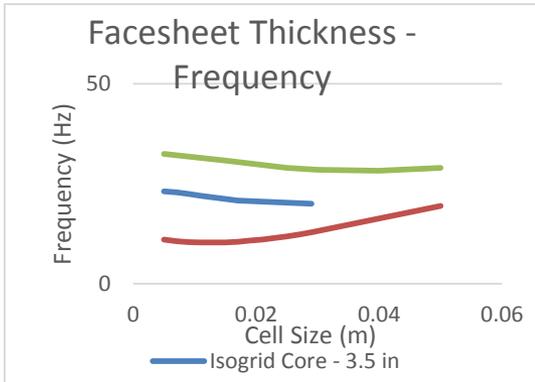
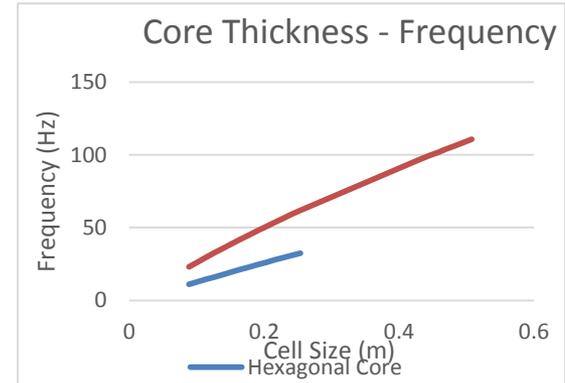
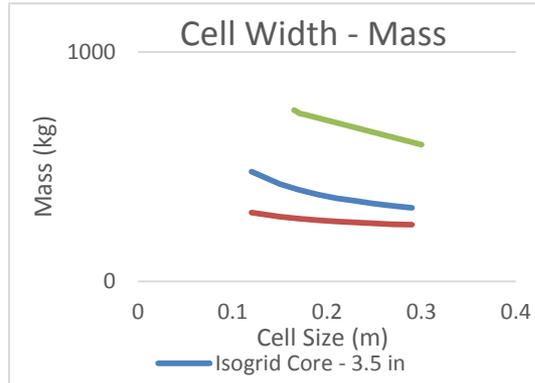
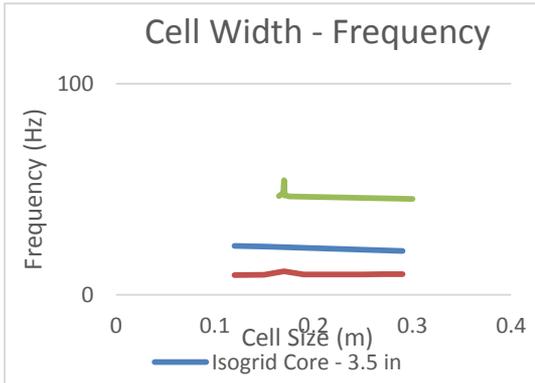
Options:  Isogrid Front,  Isogrid Back,  Backface Holes,  Include Fillets,  Off Center Pattern,  No Backsheet,  Central Hole,  Omt Central Sgmt,  Variable Facesheet,  Sofia Style Edge,  Isogrid Core,  ANSYS Legacy Eloms

Supports:  By Segment,  Whole Mirror

**Modeler Statistics**



# Typical Trade Studies Within a Design point



# Cost and Risk Estimation



- **Costs**

- Initial fabrication costs
- Transportation and handling costs
- Optical processing costs
- Testing costs
- Coating costs
- Integration into satellite costs
- Launch costs

Model Statistics	
3132	num Nodes
4656	num Elems
215.2523	Weight (kg)
1.680585	Area (m <sup>2</sup> )
128.0818	AD (kg/m <sup>2</sup> )
110.9181	Faces (kg)
104.3331	Core (kg)
20.80016	Edges (m)
0	Milled (m <sup>3</sup> )

- **Risks**

- At each stage what happens if damaged

# Tools Being Developed



- Integrated Optical Analysis System
  - Standardized inputs
- Thermal Analysis System
  - Shares models with structural analyses tools
- Structural Analysis Tools
  - Arnold Mirror Modeler supports commercial FEA packages and both monolith and segmented mirror and support systems.
- Cost and Risk Assessment Tools

# Path Forward



- Continue integration of various design tools
- Mature likely manufacturing methods
- Explore new materials or refine existing methods for 4 meter class mirrors and beyond
- Explore segmented versus monolith rationale

# Summary & Conclusions



- The goal is the design of a realistic next generation successor to the James Webb Space Telescope.
- Applying systematic approach
- Byproducts of effort useful to all aspects of telescope design ... terrestrial or space.